INDIAN NOTES AND MONOGRAPHS

EDITED BY F. W. HODGE

No. 45

A SERIES OF PUBLICATIONS RELATING TO THE AMERICAN ABORIGINES

MORPHOLOGICAL AND METRICAL VARIATION IN SKULLS FROM SAN MIGUEL ISLAND, CALIFORNIA

II. THE FORAMEN MAGNUM: SHAPE, SIZE, CORRELATIONS

BY

BRUNO OETTEKING

NEW YORK
MUSEUM OF THE AMERICAN INDIAN
HEYE FOUNDATION
1928

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II. The Foramen Magnum: Shape, Size, Correlations

By Bruno Oetteking

1. INTRODUCTION

THE following study represents the second investigation of a series of skulls from San Miguel island, California, the more complete data of which may be found in the introduction to the author's first paper in this series on the Sutura Nasofrontalis.[1] The number of skulls examined in the present study comprise 67 males, 16 females, and 4 infantiles.

The factors which govern the shape and size of the foramen magnum, and its correlative position in the cranial complex, are the same as those which govern the development of any other detail in the human organism: physiologic demand (function, adaptation) and heredity. The factors of decisive importance in our case are (1) the marvelous growth of the brain in the course of mammalian evolution,

[1] *Indian Notes and Monographs*, vol. VII, no. 2, 1920.

and (2) in connection therewith the acquisition of the erect gait. It was shown by *Bolk* (1915) that the shifting or migration of the foramen magnum from a postero-occipital to an infero-occipital (basilar) location was due to the rapid expansion of the brain, whereas the modifications of shape and size of the foramen magnum are influenced by the erect gait which imposes increasingly changing demands on the statics and dynamics of the human head, as controlled by muscular action. Mutual interrelations prevailing in the skeleton in general must also be considered in this connection with regard to the cranial complex, and which give rise to correlations between the cranial parts.

So far as can be learned, a systematic investigation of such correlative factors does not appear to have been carried on. Conjectures, however, as to the mutual relation between the size of the foramen magnum and that of the entire cranium and stature are occasionally met in anthropological literature (*Hrdlička*, 1906, 54; 1907, 31; 1909, 195; 1916, 31–32; *Hooton*, 1920, 98, et al.).

2. PROBLEM

The present investigation concerns itself with the descriptive and metrical interpretation of the foramen magnum, in the following order: (1) shape, (2) size, (3) angular conditions, and (4) correlative conditions. These latter are enhanced by classificatory comparison of absolute and proportional

measurements of the foramen magnum with those of the cranium as a whole.

3. SHAPE OF FORAMEN MAGNUM

Owing to the general uncertainty of shape of the foramen magnum, it is rather difficult from the cranioscopic angle to describe or point out definite and unmistakable types in a given series. Its variableness may well be likened to that of the cranial form itself. While in this latter respect a number of individuals may be grouped around more primary or conservative types, a certain prevalence of shape may obtain also with regard to the foramen magnum. Such primary forms may be the elliptic and circular ones which, however, even if true to type, only rarely represent racial characters of diagnostic value. In this respect the modifications of the primary shapes are of far greater occurrence. *Hooton* (1920, 112) thus distinguishes in the Madisonville crania between irregular, half-diamond, round, diamond, and hexagonal, while the present author in the Jesup Report (1929) recognizes round and elliptic as fundamental shapes with modifications in the rhomboid, and in the oval with anteriorly or posteriorly situated bases. A racial prevalence may at times be encountered, as *Haberer* (1902, 87), for instance, claims of the Chinese when he says, "Das Foramen magnum ist gewöhnlich gross, rhombisch und hat rauhe dicke Ränder," or *Klaatsch* (1908, 127), of the Australians, stating that "the

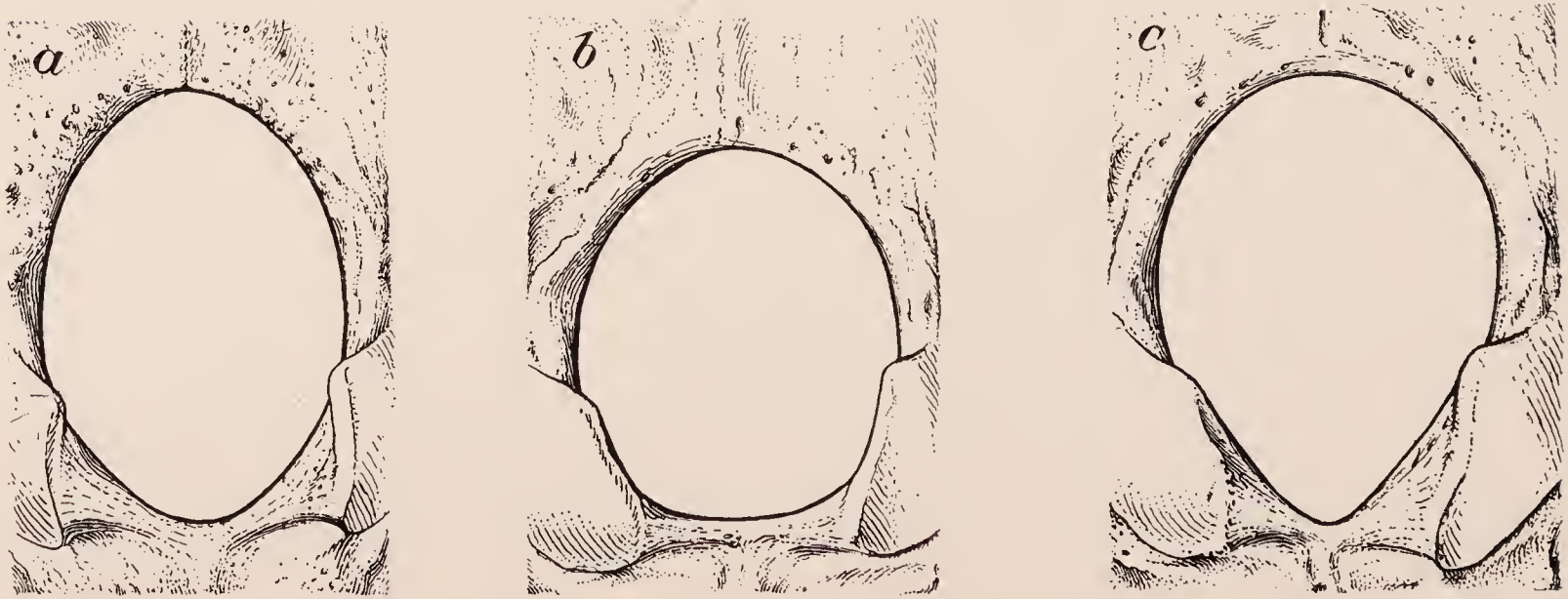


FIG. 1.—The three prevalent shapes of foramen magnum in the San Miguel Island series = *a*, elliptic (314 ♀); *b*, circular (278 ♀); *c*, oval pointed anteriorly (257 ♂). Slightly reduced.

diameter of the foramen shows much variation, an oval shape being the prevailing rule," but mentioning also circular forms.

In the series under discussion the author has applied the distinction of shapes as described in the preceding paragraph without, however, accounting for the anteriorly pointed oval and the rhomboid, true instances of which were not available. Regarding the latter it should be mentioned that the projection of the occipital condyles into the lumen of the foramen magnum frequently causes the erroneous impression of a rhomboid foramen magnum which in fact it is not. It must furthermore be remembered that since true types are rather rare, their modifications are somewhat difficult to recognize, and their classification, therefore, is somewhat arbitrary. Thus, elliptic and oval shapes may be very similar, while both may be quite wide and show affinity to the circular shape.

Taking all these fallacies into consideration the following distinction was finally decided on: (1) elliptic, (2) circular, and (3) anteriorly pointed oval, which may be seen illustrated in fig. 1, *a–c*, after specimens in the series under discussion. Their distribution among our series is shown in Table I, where the percental participation of the different shapes is highest in the circular, slightly less in the elliptic, and still less, although at an appreciable figure of 21.7%, in the oval. The distribution among the sexes is quite interesting. Equal fre-

TABLE I. *Actual and Percental Frequency of Foramen Magnum Shapes*

Classes	Elliptic		Circular		Oval anteriorly pointed	
Total	31	37.3%	34	41.0%	18	21.7%
♂.....	26	83.9%	25	73.5%	15	83.3%
♀.....	5	16.1%	7	20.6%	3	16.7%
Inf.	—	——	2	5.9%	—	——

quencies of the elliptic and oval shapes occur in the males at 83% and in the females at 16%, while in the circular there is a relatively lesser frequency in the males and a higher one in the females. The two infantiles are also listed in the column headed circular.

Irregularities around the foramen magnum, such as the various "manifestations of the occipital vertebra" (*Kollmann*, *Bolk*),[2] or others resulting from pathological or mechanical causes, do not obtain in our series. There is, however, a variation in the posterior border of the foramen which deserves mention. In ontogenetic stages an independent bone, medially situated, is derived from a special ossification center in the cartilaginous matrix, *Hannover's* (1881) membrana spinoso-occipitalis. Normally this small bone in proper time, i.e. several years after birth, according to *Gegenbaur*

[2] See *Oetteking*, *Bruno*, 1923.

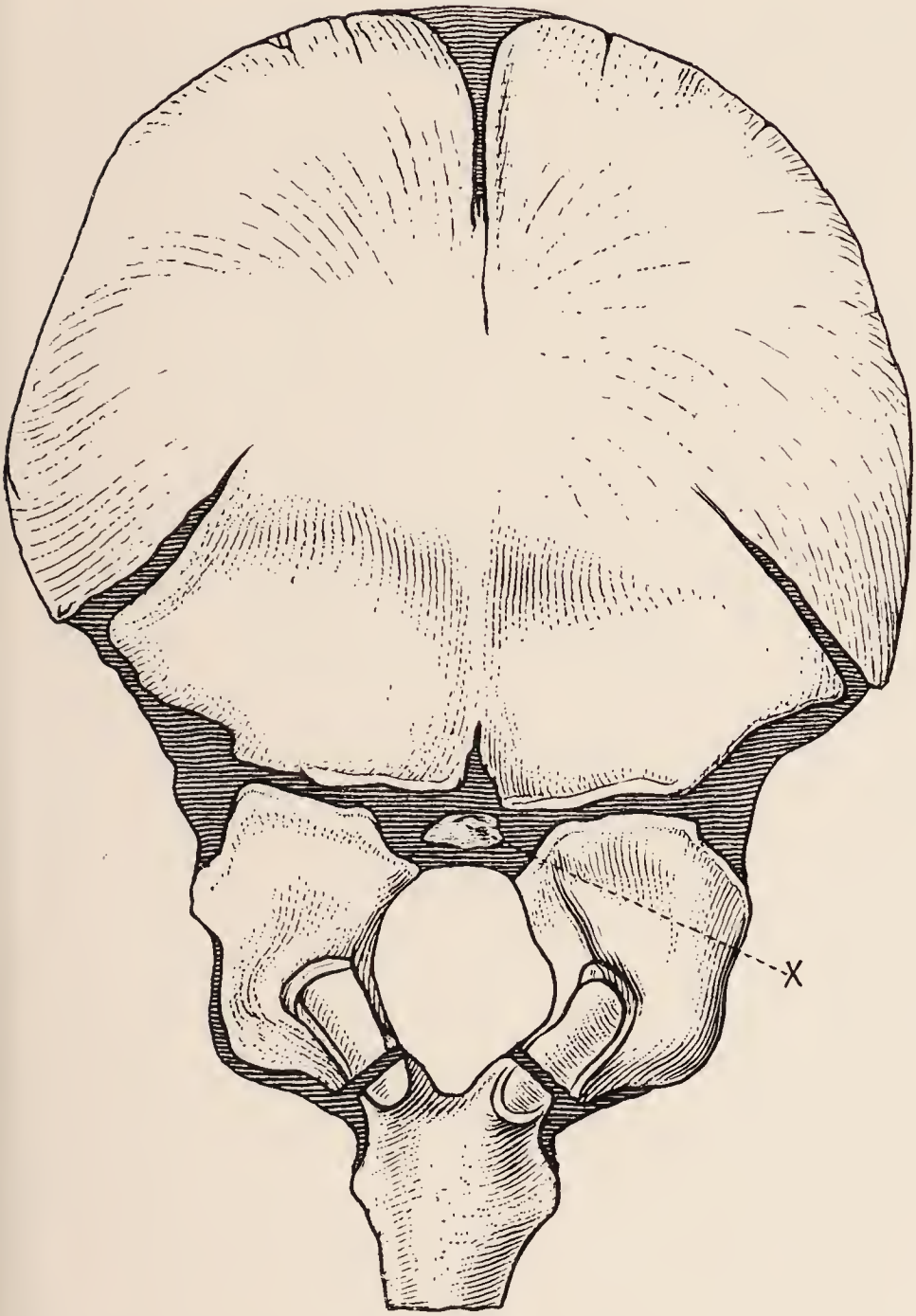


FIG. 2.—Anlage of an ossiculum *Kerckringii* (*Topinard*), x, in a fetal human os occipitale. (After *Cunningham, D. J.*, Textbook of Anatomy, 1923, p. 196.)

in the sixth to seventh year, merges with the surrounding occipital parts. This osseous element is the ossiculum *Kerckringii* (*Topinard*), or manubrium squamæ occipitalis (*R. Virchow*), the anlage of which is shown in the fetal bone of fig. 2. In rare cases it does not merge, and this produces an emargination with more or less sharp edges which then causes an elongation of the foramen. Our series does not contain such cases; a number of them instead, however, show peculiar shapings of the opisthion region which bear evidence of individually variable ossification. They are easily definable as straight and more or less angularly set off against the lateral margins of the foramen magnum, or as concave or convex. In fig. 3, *a–e*, these variations are illustrated, *a* representing the normal condition of an even rounding, as in no. 314 ♀ of our series. A straight line, 10 mm. in length, forming mildly obtuse angles at both ends, may be noticed in *b*. It is an immature skull of the infant I stage, no. 267, the permanent molars not having erupted as yet. This is a particularly interesting case because of the fact that the two lateral sutures (fissures?) at each end of the straight line had not become obliterated, which corroborates *Gegenbaur's* statement, referred to above, of mergence of the ossiculum *Kerckringii* during childhood. A modification of fig. 3, *b*, is pictured in *c*, corresponding to no. 337 ♂ of our series, where the straight line that marks the medial posterior edge of the foramen magnum turns sharply

FIG. 3.—Variation in the anomalous emargination of the posterior border of the foramen magnum. See text. Slightly reduced.

forward at right angles. These side lines again form more or less pronounced angles with the lateral margins of the foramen magnum. If the latter were connected with one another from side to side, a rectangle of only 3 mm. in depth and 10 mm. in width would result. The concave shape, as given in *d* of our figure, is that of no. 272 ♂; it represents a neatly shaped notch, while in *e*, no. 301, inf. II, where the medial portion bulges out and produces a convexity forward, this seems to be partly filled in again. Most of these shapes represent single occurrences in our series, and might be attributed directly to irregular ossification. A deficiency there of the independent osseous element hardly comes under consideration, since the notches are not deep enough to justify such an assumption. Nor on account of their scarcity can they be regarded as a racial trait, although *Klaatsch* (1908, 127 and plates) has repeatedly observed them in his Australian skulls, and *Cameron* (1923, 41c) in the Eskimo. But even in pronounced cases of absence of the ossiculum *Kerckringii*, such a condition must not be mistaken for knife-marks caused in maceration which at times occur somewhat regularly and which *Hrdlička* (1907, 91) mentions in discussing the Gilder Mound crania of Nebraska.

4. METRICAL DEFINITION OF FORAMEN MAGNUM

a. Length

The physiological range of the length of the foramen magnum in our series is almost identical in the sexes, extending from 29–38 mm. in the males and from 29–37 mm. in the females, while the two immatures measure 31 mm. and 33 mm. This is fairly in accord with *Martin's* (1928, 851) statement of a total physiological range of (25 mm.) 30 mm. to 40 mm. (43 mm.) where the parenthesized figures represent the extreme values of a Bashkir and a Tyrolese in the order of the citation. The averages amounting to 33.6 mm. in the males, 32.8 mm. in the females, and 32.0 mm. in the immatures, although quite similar, exhibit nevertheless such differences as are generally met between the sexes, as well as between the mature and immature ages, i.e. the male values exceeding the female, and the latter the immatures. If compared with other human groups, the foramen magnum length in our series is rather small, as may be seen in Table II.[3] The Japanese as well as the Australian averages exceed those of our series, and the La Chapelle-aux-Saints value of 46 mm. appears to be the highest on record.

[3] Comparative data here as elsewhere are in most cases quoted from *Rud. Martin*, Lehrbuch der Anthropologie (1928).

TABLE II. *Comparative Averages of the Foramen Magnum Length*

Classes	Length of foramen magnum (averages)			
	San Miguel Island	Japanese	Australians	La Chapelle-aux-Saints
♂....	33.6 mm. (67)	36.5 mm.	35.5 mm.	
♀....	32.8 mm. (16)	36.5 mm.	34.0 mm.	
Inf....	32.0 mm. (2)	——	——	46 mm.
Range.	29–38 mm. (85)	——	——	

b. WIDTH

The range of the foramen magnum width, like the length, comprises 10 units, extending from 24–33 mm., which at the same time represents our male range, the female extending from 24–31 mm., and that of the four infantiles from 26–28 mm. *Martin's* (1928, 851) general range comprises individual width values from (20 mm.) 23 mm. to 38 mm. where the parenthesized low extreme is that of a Roumanian. Our highest value of 33 mm. is thus seen to fall noticeably short of *Martin's* highest one. Our averages of 28.6 mm., 27.3 mm., and 27.0 mm. in the sexes and immatures, as listed in Table III, show a tendency toward smallness. The width averages manifest similar diversities to those found in the length averages. Comparison of these figures and those of the other human varieties quoted in Table II reveals similar proportions within each set of averages. It must be noted, however, that

the average of the foramen magnum width in the Japanese females at 26.5 mm., considering the smallness of the measurement, is markedly less than that of the Japanese males, as against the equality of their foramen magnum length measurements at 36.5 mm. The foramen magnum width of the La Chapelle-aux-Saints skull falls likewise considerably short of its excessive length, being thus rather comparable with the male width average of the Japanese, which in turn is slightly in excess of the width average of our own series.

TABLE III. *Comparative Averages of the Foramen Magnum Width*

Classes	Width of foramen magnum (averages)			
	San Miguel Island	Japanese	Australians	La Chapelle-aux-Saints
♂	28.6 mm. (67)	30.3 mm.	29.9 mm.	
♀	27.3 mm. (16)	26.5 mm.	29.3 mm.	30 mm.
Inf....	27.0 mm. (14)	——	——	
Range.	24–33 mm. (87)	——	——	

c. LENGTH-WIDTH INDEX

The total range of the foramen magnum index is very extensive between the extreme values of 71.4 and 103.5, both being males. The female range between 72.7 and 93.1 is less extended, while the two infantiles have indices of 81.8 and 83.9. In correspondence with the length-width differences

within and between the sexes, the male average of 84.8 slightly exceeds the female of 83.2. This condition is much more marked in the Japanese of Table IV, whose considerably smaller female average

TABLE IV. *Comparative Averages of the Foramen Magnum Index*

Classes	Foramen magnum index			
	San Miguel Island	Japanese	Australians	La Chapelle-aux-Saints
♂....	84.8 mm. (67)	83.4 mm.	84.9 mm.	
♀....	83.2 mm. (16)	72.6 mm.	86.1 mm.	
Inf....	82.0 mm. (2)	——	——	65.2 mm.
Range.	71.4–103.5 mm. (85)	—	——	

is the result of the noticeably lesser female foramen magnum width as against the higher male width and the equality of the foramen magnum length in the Japanese sexes of Table II. The La Chapelle-aux-Saints index of 65.2 appears to be the smallest on record, owing to the excessive length and the relatively small width of this fossil's foramen magnum.[4] From *Martin's* (1928, 851–852) figures it may be gathered that the physiologic range of the foramen magnum index, 71–111, is very extensive and comparable somewhat to the range of the series

[4] See, however, Table XI (Eskimo) and accompanying text on page 34.

under discussion. The average of the latter when judged by *Martin's* list of racial averages occupies a submedium position, thus indicating a slight tendency toward a bilaterally narrowing circular form. They are exceeded toward the other extreme by a number of varieties like the Bavarians, Malays, Paltacalo Indians, and others. In the majority of cases the female average falls short of the male, which speaks for a rounder foramen magnum in the latter. The reverse is shown in the Australians of Table IV.

d. Module

Inasmuch as there is considerable irregularity and little special significance in the ratio between the two main diameters of the foramen magnum, *Hrdlička* (1916, 31–32), for comparative purposes, prefers the foramen magnum module according to the formula $\frac{\text{length} + \text{width}}{2}$. The sex differences here, of course, correspond to those of the index, i.e. there is a slight diminution in the female average. Thus, while the male average of the module amounts to 30.9, at a range from 27.0–35.0, the female average yields 29.7 at a slightly smaller range from 27.5–33.5. The two infants fall within the general range of variation with values of 28.5 and 30.0. The following table lists a few comparative data, where those of the other Indians are quoted from *Hrdlička* (1916, 32).

It will be noticed that the San Miguel Island

TABLE V. *Comparative Averages of the Foramen Magnum Module*

Classes	Foramen magnum module			
	San Miguel Island	Arkansas	Munsee	La Chapelle-aux-Saints
♂....	30.9 mm. (67)	33.0 mm. (22)	35.0 mm. (7)	
♀....	29.7 mm. (16)	31.0 mm. (16)	32.0 mm. (8)	38.0 mm.
Inf....	29.3 mm. (2)			
Range.	27.0–35.0 mm.		31.0–38.0 mm. (15)	

averages are exceeded by the Arkansas and Munsee, and these again by the Chapelle-aux-Saints module of 38.0 mm. A module of the same height occurs in the Munsee range as listed in Table V.

e. ANGULAR RELATION TO EAR-EYE PLANE

The angle is formed by the basion-opisthion line representing the foramen magnum plane, and the ear-eye plane, or better, its parallel through the basion. Using *Broca's* terminology, the angle is positive (+), if situated above that parallel, and negative (−), if situated below it. Both angles open posteriorly. In fig. 4 these conditions are schematically illustrated. The positive angle, considered from a morphologic viewpoint, is a primitive condition found in Simiidæ where it ranges from

+ 55° (Cebus) to + 19° (Gorilla). More advanced conditions obtain in the extinct and recent varieties of Homo, while in the Hominidæ as shown in the La Chapelle-aux-Saints skull, the more primitive angle of + 7° occurs. However, instances of positive angles occur also in almost any human

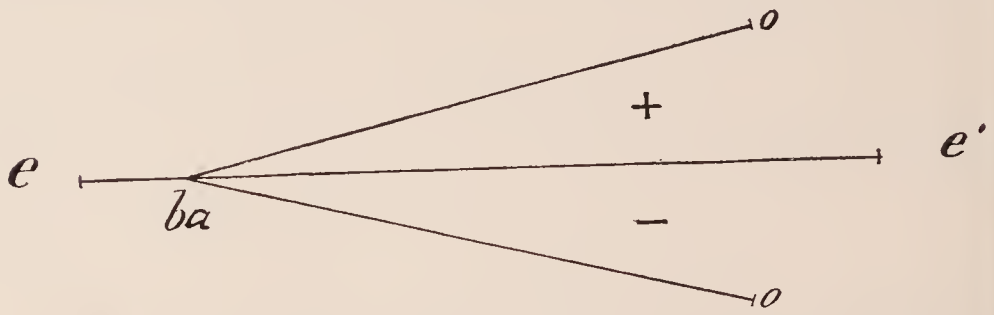


FIG. 4.—Schematic representation of the deviations of the foramen magnum plane from a parallel of the ear-eye plane (*e–e'*) passing through the basion. + angle above, – angle below, the parallel; *ba*, basion; *o*, opisthion.

variety, while the general behavior here is that of an advanced morphologic state as signified by the preponderance of the negative angle. In Europeans *Fr. Sarasin* (1916–1922, 195) states an average of – 12°, while in New Caledonians the males yielded an average of – 3°, the females of – 6.7°. Compared with these findings the San Miguel Island averages and those of the western Eskimo of Table VI range somewhat higher, falling in fact between the more primitive New Caledonians and the more advanced Europeans. One feature, however, is common, or at least preponderant, in all the varieties, i.e. the greater minus angle in the female

skulls which probably is due to the sex differences in general cranial structure.

In the present series only one instance of a positive angle has been met, the general range beginning at + 3° and extending to − 22°. The averages yield angles of − 9.4° for the males and − 13.2° for the females, and from whose range of − 5° to − 22° a higher average might have been anticipated. The two immatures have angles of − 7° and − 11°.

TABLE VI. *Comparative Averages of the Foramen Magnum Angle*

Classes	Foramen magnum angle		
	San Miguel Island	Eskimo[5] Alaska and Siberia	Chinook (deformed)
♂	− 9.4° (67)	− 7.1° (32)	+ 0.6° (56)
♀	− 13.2° (14)	− 9.8° (12)	− 0.5° (24)
Inf....	− 9.0° (2)		
Range.	+ 3° to − 22° (83)	+ 2° to − 19° (44)	+ 14° to − 15° (80)

It is of interest in this connection to compare the status of the foramen magnum angle in a deformed

[5] The data of the last two columns of Table VI are from the present author's report, now in print, on the North Pacific crania of the Jesup Expedition. Regarding the Chinook findings, see also *Oetteking, Bruno* (1924), Declination of the Pars Basilaris in Normal and Artificially Deformed Skulls, *Ind. Notes Monogr.*, misc. 27.

group. Among the skulls mentioned in footnote 5, there is a series of 56 male, 24 female, 5 infantile, and 4 juvenile Chinook skulls. This tribe, as is known, practised excessive anteroposterior skull deformation which, besides causing considerable distortion in the configuration of the skull parts, brought about changes at the base of the skull. The total range of variation comprises angles from + 14° to − 15°, and it is quite significant that the infantile and juvenile ranges contain only plus values + 7° to + 4° in the former, and + 8° to 0° in the latter, while the male and female ranges extending into the minus region amount to + 14° to − 15° in the former, and + 7° to − 10° in the latter. The averages accordingly aggregate + 0.6° in the males, − 0.5° in the females, + 5.2° in the infantiles, and + 3.0° in the juveniles.

5. CORRELATIONS

The morphological interpretation of so complex a unit as the human skull must needs rely, to its greater extent, on quantitative determinations. Diameters and their proportional relations expressed in percental indices, however, do not fully solve the problem: they disclose only insufficiently the interdependence of parts in the configurative sense. Thus, while quantitative determination must be the basis of all differential treatment, the interpretation of form may be greatly aided through the

examination of the correlations of parts that form the complex. Although different methods were applicable and suitable to our specific use, the counterposition of metrical findings was preferred, the problem thus treating of the correlation between the dimensions, shape, angular position of the foramen magnum, and certain cranial dimensions and proportions.

In the order of their importance the investigation of mutual relation was carried on, first, between absolute measurements of the foramen magnum and the cranium; secondly, between their proportional evaluations; thirdly, between the foramen magnum angle, and absolute foramen magnum and cranial measurements, and the proportional evaluations of the latter.

a. Mutual Relation between Absolute Cranial and Foramen Magnum Measurements

α. cranial length and foramen magnum length

The averages of cranial length in the present series amount to 177.0 mm. and 170.1 mm. in the sexes, and 160.7 mm. in the infantiles. They show the usual sex difference, ranging rather low when compared to other racial averages given by *Martin* (1928, 765) with male and female ranges of 174 mm. (Bashkirs) to 187 mm. (Scotch), and 165 mm.

TABLE VII. *Correlation between the Cranial and Foramen Magnum Lengths (Frequencies, Averages, Ranges)*

Series	Length			
	Cases	Cranial	Cases	Foramen magnum
San Miguel Island				
♂	68	177.0 (168–193) mm.	67[6]	33.6 (29–38) mm.
♀	16	170.1 (164–175) mm.	16	32.8 (29–37) mm.
Inf.	6	160.7 (155–166) mm.	2	32.0 (31, 33) mm.
Eskimo (West)[7]				
♂	33	181.9 (167–192) mm.	32	37.1 (33–44) mm.
♀	12	173.2 (166–179) mm.	11	35.5 (33–40) mm.
La Chapelle-aux-Saints		208 mm.		46 mm.

[6] Inconsistencies here and farther on in the number of cases in each of the correlated measurements, 68 against 67 male and 6 against 2 infantile cases in the two measurements of Table VII, are naturally due to the feasibility of the latter being taken.

[7] See footnote 5.

(Telengets) to 179 mm. (Scotch) respectively. In Table VII the length averages of the cranium and the foramen magnum of our own series are contrasted with those of another group and a neandertaloid specimen.

From this tabulation it appears that an increasing cranial length as represented by the sex averages is associated with an increasing foramen magnum length, a fact which is evident in our own series as well as in the Eskimo and the human fossil listed there. As to the differential correlation between the two diameters under investigation within our series, the cranial length as shown in Table VIII was divided into three classes, containing the individual values from 164–169 mm., 170–179 mm., and 180–189 mm., and the foramen magnum length computed for each of these classes. The infantiles, on account of their small number, have not been listed in the tables, but are mentioned in each case in the discussion.

In the males, the foramen magnum length for the division of smallest cranial length with 34.8 mm. slightly exceeds that for the medium class with an average of 33.0 mm., only to increase again to 34.7 mm. with the class of greatest cranial length. It is quite possible that the disparity of successive increase in the male averages is due to the small number of cases in the class of lowest cranial length. The fact, however, that high individual values occur there cannot be disputed. In the females whose

TABLE VIII. *Correlation between the Cranial and Foramen Magnum Lengths, Classified (San Miguel Island)*

Cranial length (classified)	Length of foramen magnum							
	♂				♀			
	Cases	Average	Range		Cases	Average	Range	
164–169 mm. . . .	4	34.8 mm.	32–37 mm.		6	32.0 mm.	29–36 mm.	
170–179 mm. . . .	41	33.0 mm.	29–38 mm.		10	33.2 mm.	33–37 mm.	
180–189 mm. . . .	22	34.7 mm.	31–37 mm.		—	——	——	

averages comprise only the first two classes, the smaller cranial length combines itself with the lower average of the foramen magnum length, while the medium class shows an increase over the two. Two infantile skulls with foramen magnum lengths of 31 mm. and 33 mm., as specified in Table VII, have smaller cranial lengths of 161 mm. and 166 mm., which establishes the expected correlation between the two measurements. Some significance, however, seems to attach to the ranges of the foramen magnum length classes as correlated with those of the cranial length. Thus, while the female ranges show an even increase, the male ranges are per-

fectly irregular, which may be due in part to the small number of cases in the class of shortest cranial lengths, as pointed out above.

β. CRANIAL BREADTH AND FORAMEN MAGNUM WIDTH

The two breadth measurements, the cranial and that of the foramen magnum, have been treated in the same way as the respective lengths in the preceding section. In Table IX both measurements are contrasted.

On the basis of *Martin's* (1928, 766) list where the male averages for the cranial breadth range from 128 mm. (Vedda) to 153 mm. (Buriats), and the female from 124 mm. (Vedda, Paltacalo Indians) to 145 mm. (Swiss [Wallis], Telengets), showing the usual sex differences, the San Miguel averages as recorded in Table IX must be characterized as rather submediun. There are also among the individual values, if compared with *Martin's* physical range of from 101–173 mm., only few above medium conditions. The La Chapelle-aux-Saints skull, quite in proportion with its inordinate length, is seen to exceed in cranial breadth any of the San Miguel and Eskimo specimens, while the latter exceed the San Miguel skulls by only a trifle. As regards the foramen magnum width of the La Chapelle-aux-Saints skull, this falls, with 30 mm., about half-way between the extreme values of the Eskimo male range, a relation which will be of significance in the

TABLE IX. *Correlation between the Cranial Breadth and Foramen Magnum Width (Frequencies, Averages, Ranges)*

Series	Cases	Cranial breadth	Cases	Foramen magnum width
San Miguel Island				
♂	68	139.7 (130–151) mm.	67	28.6 (24–33) mm.
♀	16	135.3 (130–140) mm.	16	27.3 (24–31) mm.
Inf.	6	132.7 (129–138) mm.	4	27.0 (26–28) mm.
Eskimo (West)				
♂	33	140.0 (130–150) mm.	33	29.3 (27–33) mm.
♀	12	136.1 (130–142) mm.	11	28.6 (26–32) mm.
La Chapelle-aux-Saints		156 mm.		30 mm.

length-breadth and length-width indices treated in the following section.

Comparable to the length measurements of the San Miguel Island skulls, those of the cranial breadth and the foramen magnum width show similar correlations. There is in the two groups of Table IX an increase of the foramen magnum width observable along with the increase of the cranial breadth. If, however, the cranial breadth is divided into successive small groups, to which the foramen mag-

num width is brought in proportion, such a correlation becomes less evident, as is shown in Table X. Here the range of the cranial breadth is divided into four classes and the foramen magnum widths correlated with each of them.

As is the case in the length measurements, in the females there is to be noticed an increase in the two successive classes with averages of 26.8 mm. and 27.9 mm., which is likewise obvious in the two ranges, 24–28 mm. against 26–30 mm. Such an increase is less clear in the males, each of whose four class averages amounts to

TABLE X. *Correlation between the Cranial Breadth and the Foramen Magnum Width, Classified (San Miguel Island)*

Cranial breadth (classified)	Width of foramen magnum							
	♂			♀				
	Cases	Average	Range	Cases	Average	Range		
130–135 mm.	14	28.5 mm.	24–33 mm.	8	26.8 mm.	24–28 mm.		
136–140 mm.	25	28.6 mm.	24–32 mm.	8	27.9 mm.	26–30 mm.		
141–145 mm.	23	28.6 mm.	25–33 mm.	—	——	——		
146–151 mm.	5	28.8 mm.	28–31 mm.	—	——	——		

28 mm. and fractions, and it is only by the latter and by the ranges of the four classes that an increase, however slight, may be realized. Four infantiles with cranial breadths between 129–138 mm. have also small foramen magnum widths of an increasing order from 26–28 mm.

b. Mutual Relation between Proportional Evaluations

α. cranial length-breadth index and foramen magnum index

The averages of the cranial length-breadth index show the typical increase in the order males, females and infantiles, and, with the exception of the latter who are brachycranial, fall into the mesocranial class. This is also true of the Eskimo included in Table XI. In the San Miguel skulls the averages of the foramen magnum index when compared with those of the cranium show a gradual decrease as against the increasing cranial averages. These conditions, however, are reversed in the Eskimo in such a way that with the increase of sex averages the foramen magnum index likewise increases. This being also the case with the Australians of Table IV, it may be assumed that the proportions between the averages of the foramen magnum index in the various groups of mankind vary as to sex. The

TABLE XI. *Correlation between the Cranial Length-breadth and the Foramen Magnum Index (Frequencies, Averages, Ranges)*

Series	Length-breadth (width) index			
	Cases	Cranial	Cases	Foramen magnum
San Miguel Island				
♂	67	78.4 (71.9–83.9) mm.	67	84.8 (71.4–103.5) mm.
♀	16	79.2 (77.0–83.3) mm.	16	83.2 (72.7–93.1) mm.
Inf.	6	82.3 (80.1–85.3) mm.	2	82.0 (81.8, 83.9) mm.
Eskimo (West)				
♂	33	77.0 (71.0–81.7) mm.	32	78.7 (62.8–91.2) mm.
♀	12	79.0 (74.4–83.3) mm.	11	80.4 (70.3–91.4) mm.
La Chapelle-aux-Saints	75.0		65.2	

TABLE XII. *Correlation between the Cranial Length-breadth and the Foramen Magnum Index, Classified (San Miguel Island)*

Cranial length-breadth index (classified)	Foramen magnum index					
	♂			♀		
	Cases	Average	Range	Cases	Average	Range
71.9–74.9 mm.	5	79.8 mm.	77.8–83.3 mm.	—	——	——
75.0–79.9 mm.	39	84.8 mm.	75.0–97.1 mm.	10	79.4 mm.	72.7–86.1 mm.
80.0–84.2 mm.	23	85.8 mm.	71.4–103.5 mm.	6	89.5 mm.	84.9–93.1 mm.

lowest foramen magnum index of 65.2 of Table XI (La Chapelle-aux-Saints), to which reference was made on page 19, is exceeded by the still lower male value of 62.8 in our Eskimo group and which is naturally an extraneous case, the next higher being 73.0 in the same range.

The comparison of the foramen magnum and cranial length-breadth indices in our series within definite subdivisions of the latter, as shown in Table XII, reveals the fact of a gradual increase in the averages of those subdivisions in the sexes. This is in contrast to the general behavior of the sex averages as pointed out in the preceding paragraph.

β. CRANIAL AND FORAMEN MAGNUM MODULES

Both modules depend entirely upon the cranial dimensions in general and represent as such synthetic size expressions, varying naturally in the sexes in such a way that the male averages exceed the female, and these in turn the infantile. This is likewise the case with the foramen magnum modules as shown in Table XIII. On account of their greater cranial dimensions, the

TABLE XIII. *Correlation between the Cranial and Foramen Magnum Modules*

Series	Module			
	Cranial		Foramen magnum	
	Cases		Cases	
San Miguel Island				
♂	67	148.0 (141.0–156.3) mm.	67	30.9 (27.0–35.0) mm.
♀	16	142.3 (138.0–147.0) mm.	16	29.7 (27.5–33.5) mm.
Inf.	2	138.0 (134.7, 142.7) mm.	2	29.0 (28.5, 30.0) mm.
Eskimo (West)				
♂	32	152.3 (143.3–162.0) mm.	32	33.0 (30.5–35.5) mm.
♀	11	146.9 (144.3–150.0) mm.	11	31.9 (30.5–38.0) mm.
La Chapelle-aux-Saints.		165.0		38.0

TABLE XIV. *Correlation between the Cranial and Foramen Magnum Modules, Classified (San Miguel Island)*

Cranial module (classified)	Foramen magnum module						
	♂			♀			
	Cases	Average	Range	Cases	Average	Range
138.0–144.7 mm.	15	30.5 mm.	27.0–34.0 mm.	13	29.4 mm.	27.5–33.5 mm.
145.7–150.7 mm.	34	30.7 mm.	28.0–35.0 mm.	3	31.0 mm.	29.5–33.0 mm.
151.7–156.3 mm.	18	31.4 mm.	29.5–33.0 mm.	—	——	——

Eskimo of the same table yield higher cranial modules to which the foramen magnum modules are in proportion. The highest values of our table, of which only the foramen magnum module of 38.0 is doubled in the Eskimo female range, are those of the La Chapelle-aux-Saints fossil whose cranial measurements, at least the length and breadth, were found to exceed by far the averages and ranges of the other groups of our tables,[8] this holding true also of the foramen magnum length. The high foramen magnum module of the La Chapelle-aux-Saints skull is ac-

[8] For the cranial height *Boule* gives 131 mm., a value falling well within the San Miguel and Eskimo series.

counted for by the length rather than by the foramen magnum width.

In the correlation scheme of Table XIV it is made manifest that in the males as well as in the females of the San Miguel Island series the averages of the foramen magnum modules increase proportionately in the successive classes of the cranial module.

c. Mutual Relation between the Foramen Magnum Angle and Absolute and Proportional Foramen Magnum and Cranial Evaluations

α. angle and length of the foramen magnum

From Table VI it was gathered that the sex averages for the foramen magnum angle differed in such a way that the female average yielded the higher figure, i.e. higher minus value, thus representing a more advanced morphologic condition. This held true not only for the San Miguel Island series, but also for the Eskimo of the same table, and it may be inferred that this is quite probably the general behavior in the human groups.[9]

[9] From the physeotypical viewpoint one may be led to assume that the tendency toward greater female short-headedness in the comparative sense as a response probably to the less extensive backward and the more intensive lateral and downward expansion of the brain (*Bolk*, 1915), influences the orientation of the foramen magnum plane in such a way as to force the opisthion region downward, as against the more conservative basion region, which then would account for the greater minus angle of the foramen magnum plane.

TABLE XV. *Correlation between the Angle and the Length of the Foramen Magnum (Frequencies, Averages, Ranges)*

Series	Foramen magnum			
	Cases	Length	Cases	Angle
San Miguel Island				
♂	67	33.6 (29–38) mm.	67	−9.4° (+3 to −21)
♀	16	32.8 (29–37) mm.	14	−13.2° (−5 to −22)
Inf.	2	32.0 (31; 33) mm.	2	−9.0° (−7; −11)
Eskimo (West)				
♂	32	37.1 (33–44) mm.	32	−7.1° (+2 to −19)
♀	11	35.5 (33–40) mm.	12	−9.8° (−4 to −20)
La Chapelle-aux-Saints .	46 mm.		+ 7°	

The combination in Table XV of the sex averages of the foramen magnum length and angle demonstrates, from the purely metrical viewpoint, that the smaller female average of 32.8 mm. is correlated with the larger average of − 13.2°, as against the male averages of 33.6 mm. and − 9.4°. Analogous proportions, but with comparatively higher length averages and smaller angle averages, obtain in the Eskimo, while an exaggeration of these proportions is shown by the La Chapelle-aux-Saints values.

The general trend of these proportional conditions may be seen corroborated in Table XVI, in which in the males as well as in the females the averages

TABLE XVI. *Correlation between the Angle and the Length of the Foramen Magnum, Classified (San Miguel Island)*

Foramen magnum length (classified)	Foramen magnum angle					
	♂			♀		
	Cases	Average	Range	Cases	Average	Range
29–30 mm. . .	6	−11.5°	−4° to −20°	3	−18.0°	−13° to −22°
31–35 mm. . .	47	−9.8°	−3° to −21°	8	−12.8°	−6° to −19°
36–38 mm. . .	14	−6.9°	−3° to −8°	3	−10.0°	−5° to −14°

TABLE XVII. *Correlation between the Angle and the Index of the Foramen Magnum (Frequencies, Averages, Ranges)*

Series	Foramen magnum			
	Index		Angle	
	Cases		Cases	
San Miguel Island				
♂	67	84.8 (71.4–103.5)	67	−9.4° (+3 to −21)
♀	16	83.2 (72.7–93.1)	14	−13.2° (−5 to −22)
Inf.	2	82.0 (81.8; 83.9)	2	−9.0° (−7; −11)
Eskimo (West)				
♂	32	78.7 (62.8–91.2)	32	−7.1° (+2 to −19)
♀	11	80.4 (70.3–91.4)	12	−9.8° (−4 to −20)
La Chapelle-aux-Saints		65.2		+7°

of the foramen magnum angle decrease with the increasing classification of the foramen magnum length.

β. ANGLE AND INDEX OF THE FORAMEN MAGNUM

The averages of the foramen magnum index, as specified in Table XVII, decreasing in the San Miguel Island series from 84.8 to 83.2 in the sexes, yield increasing averages of the foramen magnum angle of − 9.4° and − 13.2°

respectively; while the infantiles, numbering only two, with an index average below those of the sexes, come only to − 9.0°, a condition doubtless due to their undeveloped physical state. The different order of indices in the Eskimo, i.e. 78.7 in the males, increasing to 80.4 in the females, as previously pointed out (page 32), shows nevertheless increasing averages of the angle, − 7.1° and − 9.8°, indicating that the order of sex averages of the foramen magnum angle, i.e. increasing from male to female, is rather a stable one and, at least so far as the two human varieties of Table

TABLE XVIII. *Correlation between the Angle and the Index of the Foramen Magnum, Classified (San Miguel Island)*

Foramen magnum index	Foramen magnum angle					
	♂			♀		
	Cases	Average	Range	Cases	Average	Range
71.4–80.7	20	−7.3°	0° to −16°	4	−8.3°	−5° to −12°
81.3–90.6	36	−9.7°	+3° to −20°	9	−14.4°	−8° to −19°
91.2–103.5	11	−12.0°	−3° to −21°	1	−22.0°	——

XVII are concerned, is independent of the behavior of the foramen magnum index averages of the sexes.

While this is probably the general behavior in any series of human skulls, the distinctly increasing order of the angle averages in both sexes for the increasing classes of the foramen magnum index, as shown in Table XVIII, is quite interesting.

γ. FORAMEN MAGNUM ANGLE AND CRANIAL LENGTH

It is shown in Table XIX that the averages for the cranial length, decreasing naturally in the sexes and immatures, are correlated with increasing averages of the foramen magnum angle so far as the sexes are concerned.[10] The angle of the immatures, on the other hand, decreases again and with 9.0° falls even slightly below the average of the males. As previously mentioned, this latter condition must be attributed to the undeveloped state of the infantile cranium.

The Eskimo of the same table present analogous successive differences in the average expressions. The slightly higher averages of the cranial length are correlated with somewhat lower averages of the foramen magnum angle. This proportion is carried to excess in the La Chapelle-aux-Saints skull, whose inordinate length of 208 mm. combines itself with a

[10] See footnote 9.

TABLE XIX. *Correlation between the Foramen Magnum Angle and the Cranial Length (Frequencies, Averages, Ranges)*

Series	Cases	Cranial length	Cases	Foramen magnum angle
San Miguel Island				
♂	68	177.0 (168–193) mm.	67	−9.4° (+3 to −21)
♀	16	170.1 (164–175) mm.	14	−13.2° (−5 to −22)
Inf.	6	160.7 (155–166) mm.	2	−9.0° (−7, −11)
Eskimo (West)				
♂	33	181.9 (167–192) mm.	32	−7.1° (+2 to −19)
♀	12	173.2 (166–179) mm.	12	−9.8° (−4 to −20)
La Chapelle-aux-Saints	208 mm.		+7°	

TABLE XX. *Correlation between the Foramen Magnum Angle and the Cranial Length, Classified (San Miguel Island)*

Cranial length (classified)	Foramen magnum angle							
	♂			♀				
	Cases	Average	Range	Cases	Average	Range		
161–169 mm. . . .	4	−10.3°	−5° to −18°	6	−14.6°	−6° to −22°		
170–179 mm. . . .	41	−9.9°	+3° to −21°	8	−12.3°	−5° to −19°		
180–193 mm. . . .	22	−8.5°	−1° to −20°	—	——	——		

foramen magnum angle of even + 7°, which is, of course, of phylogenetic significance.

The correlation between the foramen magnum angle and the cranial length, i.e. the gradual decrease of the angle averages in the successive classes of the cranial length, is analogous to the foramen magnum length and angle as specified in Table XVI. This is demonstrated in Table XX and is evident in both the males and the females.

δ. FORAMEN MAGNUM ANGLE AND CRANIAL LENGTH-BREADTH INDEX

The tendency toward relative shortheadedness of the females as against the males of a

given group is also borne out in the San Miguel Island crania and the Eskimo of Table XXI. The increasing sex averages of the cranial length-breadth index indicating those conditions are prompted there by the increasing averages of the foramen magnum angle, with the difference, however, as pointed out before, that the Eskimo present, with regard to the angle, a less advanced condition. The cranial length-breadth proportion, on the other hand, is fairly uniform in both varieties, with the exception perhaps that the Eskimo

TABLE XXI. *Correlation between the Foramen Magnum Angle and Cranial Length-breadth Index (Frequencies, Averages, Ranges)*

Series	Cases	Cranial L–Br Index	Cases	Foramen magnum angle
San Miguel Island				
♂	67	78.4 (71.9–83.9)	67	−9.4° (+3 to −21)
♀	16	79.2 (77.0–83.3)	14	−13.2° (−5 to −22)
Inf.	6	82.3 (80.1–85.3)	2	−9.0° (−7; −11)
Eskimo (West)				
♂	33	77.0 (71.0–81.7)	32	−7.1° (+2 to −19)
♀	12	79.0 (74.0–83.3)	12	−9.8° (−4 to −20)
La Chapelle-aux-Saints		75.0		+7°

TABLE XXII. *Correlation between the Foramen Magnum Angle and the Cranial Length-breadth Index, Classified (San Miguel Island)*

Cranial L-Br index (classified)	Foramen magnum angle					
	♂			♀		
	Cases	Average	Range	Cases	Average	Range
71.9–74.9	6	−7.8°	−2° to −14°	—	——	——
75.0–79.9	39	−9.1°	+3° to −21°	9	−11.0°	−5° to −19°
80.0–84.2	22	−10.3°	−1° to −20°	5	−17.2°	−13° to −22°

males appear to be slightly less mesocranial.

The comparatively low index of 75.0 of the La Chapelle-aux-Saints cranium has also the least specialized angle of + 7°, the morphologic significance of which, however, lies with the difference in species.

The metrical correlations in the sexes are repeated by the classified index-angle correlations in each of them. It is shown in Table XXII that with the increasing length-breadth index classes, the sizes of the foramen magnum angles also steadily increase. The more advanced conditions in this respect are shown in the female cranium, not only by higher

angle averages for the same classes of the cranial length-breadth index, but also by the fact that in the lowest index class there is no female representative, this being, however, fundamentally a question of cranial length-breadth proportion in the females of our series.[11]

6. CONCLUSION AND SUMMARY

The preceding study concerns itself with the morphologic, metric, and correlative conditions of the foramen magnum in the San Miguel Island series of crania in the collection of the Museum of the American Indian, Heye Foundation. Regarding its shape, the foramen magnum with most cranial series shares a certain indefiniteness which in the present series is signified by a slight predominance of the circular. The frequency of this shape, however, is approached by that of the elliptic, and, to a lesser degree, by the anteriorly pointed oval. The latter two when combined exceed the frequency of the former. Anomalous formations around the foramen magnum such as the "manifestations of the occipital vertebra" (*Kollmann*) do not occur. In a number of cases notch-like dilatations were observed, too unpronounced, however, to assume a missing ossiculum *Kerckringii*, but due nevertheless to irregular ossification (fig. 3, *b–c*).

[11] In respect to this see footnote 9.

The absolute length and width dimensions of the foramen magnum show in their average conditions the typical differences, more or less stressed, between the sexes and between these, i.e. the matures and the immatures, in a diminishing order according to the differences in physical size. The average expressions for the length and width are both markedly low and rise in comparison only slightly above the lowest values of a racial range of variation. The limited dimensions of the foramen magnum are likewise evidenced by its module which in consideration of the nature of the measurements ranges on the average distinctly below the tribal varieties of Table V.

The length-width index as a proportional expression of the two principal dimensions of the foramen magnum corroborates the results of the visual examination. Its average signifies a somewhat rounded foramen with a slight tendency to narrow from side to side, which is more noticeable in the females, and in the latter appears to be the rather general occurrence in the human varieties. Exceptions to this statement occur, while on the other hand the generally close approximation of the sex averages may show stronger divergences, as, for instance, in the Japanese and Paltacalo Indians with male and female averages of 83.4 and 72.6, and 88.0 and 79.5 respectively.

Investigation of the angular position of the foramen magnum plane in the cranial complex in relation

to the general plane of orientation, i.e. the ear-eye plane, reveals several interesting results. The average angularity is marked by unmistakable differences in the human varieties. The San Miguel averages, for instance, when compared with *Fr. Sarasin's* European average of − 12°, almost equal it, while the Eskimo fall distinctly lower, as do in turn the New Caledonians and the human fossil. If this signifies racial characteristics, these are still further emphasized by the marked sex differences in each case which yield the higher averages to the females. The cause for this remarkable distinction, as suggested in footnote 9, must be attributed quite probably to sex differences of physical growth and type which primarily govern all and every physical formation and which, in this specific case of the brain, influence commensurably the form of the skull; this may, in consequence, result in the increased declination of the foramen magnum plane. Quantitatively expressible, this distinction stands out quite clearly, while physiologically no satisfactory explanation can yet be offered.

The systematic investigation of the mutual or correlative relations between certain cranial and foramen magnum measurements and proportions results in a number of interesting observations. The investigation was carried on in such a way that the sex averages of a special measurement, as well as the averages derived from its suitably divided range of variation, were placed in contrast to the sex

averages of another measurement to which they were to be compared, and to those averages of the latter as checked with the divisions or classes of the first measurement. This is shown in the subjoined table of correlations.

Definite correlations, holding good for both the sex and class averages, could be established between the principal dimensions of both the cranium and the foramen magnum to the extent that the increasing cranial length and breadth were correlated with increasing length and width of the foramen magnum and naturally for the modules implicating the additional cranial height measurement in the cranial module. The same gradual increase was observed in the divisional correlations as based on the classes of the cranial length-breadth index, but not with regard to the sex averages which, increasing in the order male-female, encountered decreasing foramen magnum sex averages in the San Miguel Island skulls, while, for instance, in the Western Eskimo and Australians, the first, i.e. increasing order, was retained. This condition is reëncountered in the combination with the foramen magnum angle where the foramen magnum index is used as a base. The conflicting order of graduation of sex averages in the latter, i.e. either increasing or decreasing in the human varieties, as pointed out in the preceding sentence, is correlated, however, under both these conditions with only increasing averages of the angle. The increasing class averages of the foramen magnum

Table of Mutual Relations (Correlations) between Average Foramen Magnum and Cranial Metrical Quantities in the Sexes and the Graded Divisions of Ranges of Variation of Basic Measurements, in Descriptive Terms. The Metrical Accounts may be Looked for in the Various Tables.

Classification	Correlated metrical quantities	
	Cranial length	Foramen magnum length
Sexes.....	Increasing	Increasing
Classes.....	Increasing	Increasing
	Cranial breadth	Foramen magnum width
Sexes.....	Increasing	Increasing
Classes.....	Increasing (only slightly)	Increasing
	Cranial L-Br index	Foramen magnum index
Sexes.....	Increasing	{ Decreasing (San Miguel Is.)
Classes.....	Increasing	{ Increasing (Western Eskimo, Australians)
		Increasing
	Cranial module	Foramen magnum module
Sexes.....	Increasing	Increasing
Classes.....	Increasing	Increasing
	Foramen magnum length	Foramen magnum angle
Sexes.....	Decreasing	Increasing
Classes.....	Increasing	Decreasing
	Foramen magnum index	Foramen magnum angle
Sexes.....	Decreasing } see third item above	Increasing
	Increasing }	
Classes.....	Increasing	Increasing
	Cranial length	Foramen magnum angle
Sexes.....	Decreasing	Increasing
Classes.....	Increasing	Decreasing
	Cranial L-Br index	Foramen magnum angle
Sexes.....	Increasing	Increasing
Classes.....	Increasing	Increasing

index, on the other hand, are prompted by increasing averages of the angle. Identical results were observed in the combinations of the cranial and foramen magnum lengths with the foramen magnum angle in such a way that with the decreasing length averages in the sexes in the order male-female, the averages of the angle increased while the increasing class averages were correlated with decreasing averages of the angle. There is another phenomenon implicated in this, namely, the higher foramen magnum angle in the female skull, i.e. its greater minus angle (page 23, Table VI) as correlated with the smaller absolute cranial and foramen magnum lengths, and vice versa. The proportions, however, between the cranial length-breadth index and the foramen magnum angle show an even progression in the sexes as well as in the classes.

The infantile values, although recorded in the tables, naturally have no significance from the viewpoint of systematic comparison. Of greater import are the findings upon the human fossil (La Chapelle-aux-Saints) which with its larger dimensions combines morphologically inferior traits of the foramen magnum, particularly with regard to the excessive length of the latter and to its markedly low foramen magnum angle (+ 7°) of phylogenetic significance.

The investigations carried on in the study of the foramen magnum of the San Miguel Island skulls give rise to the following summarization:

1. The shape of the foramen magnum is roundish.

2. Its size is submedium to small, with the typical sex difference according to physical size.

3. The somewhat smaller average of the length-width index indicates in the females a slightly narrower foramen magnum as compared with that of the males. This condition is shown to vary in the human varieties.

4. The greater degree of minus declination of the foramen magnum plane in the female crania, also in other human groups, signifies a more advanced morphologic condition.

Size and type differences in the brain, regarding which no studies have as yet been made, are doubtless causative for the varying conditions of cranial morphology in the sexes.

5. The study of mutual relations between different measurements reveals the following correlations:

a. Simultaneous increase in absolute cranial and foramen magnum measurements.

b. Varying behavior between the sex averages of the cranial L-Br index and the foramen magnum index, i.e. increasing-decreasing in the San Miguel Island skulls, but simultaneously increasing in a number of other human varieties. A simultaneous increase, however, is the distinguishing mark of the class correlation between the indices in question.

c. Foramen magnum and cranial lengths are correlated with the foramen magnum angle in such a way that with the decrease in the sex

averages of the former, increasing averages of the angle are observed, while in corroboration the increasing averages of the subdivided ranges of the former are prompted by the decreasing averages of angularity.

d. The foramen magnum index, varying in regard to the graduation of sex averages in various human groups, is correlated with invariably increasing sex averages of the angle; but simultaneous increase of averages obtains in the classified averages of both categories.

e. Simultaneous increase of sex as well as class averages was observed between the cranial L-Br index and the foramen magnum angle.[12]

LITERATURE

Bolk, Louis
1915 Über Lagerung, Verschiebung und Neigung des Foramen magnum am Schädel der Primaten. *Ztschr. Morph. Anthr.*, v. xvii, pp. 688–692.

Cameron, John
1923 Osteology of the Western and Central Eskimos. *Rep. Canadian Arct. Exped.*, 1913–18, v. xii, pt. c.

Hannover, Adolphus
1881 Le cartilage primordial et son ossification dans le crâne humain avant la naissance. (Original Danish, 1879–80.)

[12] Experiment with a number of other more or less closely related measurements of the cranium to those of the foramen magnum not recorded here, revealed similarly identical correlations.

Higher mathematical differential methods (coëfficient of correlation) were not resorted to on account of the relatively small series of specimens under investigation.

HOOTON, EARNEST A.
1920 Indian village site and cemetery near Madisonville, Ohio. *Pap. Peabody Mus. Amer. Archaeol. Ethnol. Harvard Univ.*, v. VIII, no. 1, pp. 83–137.

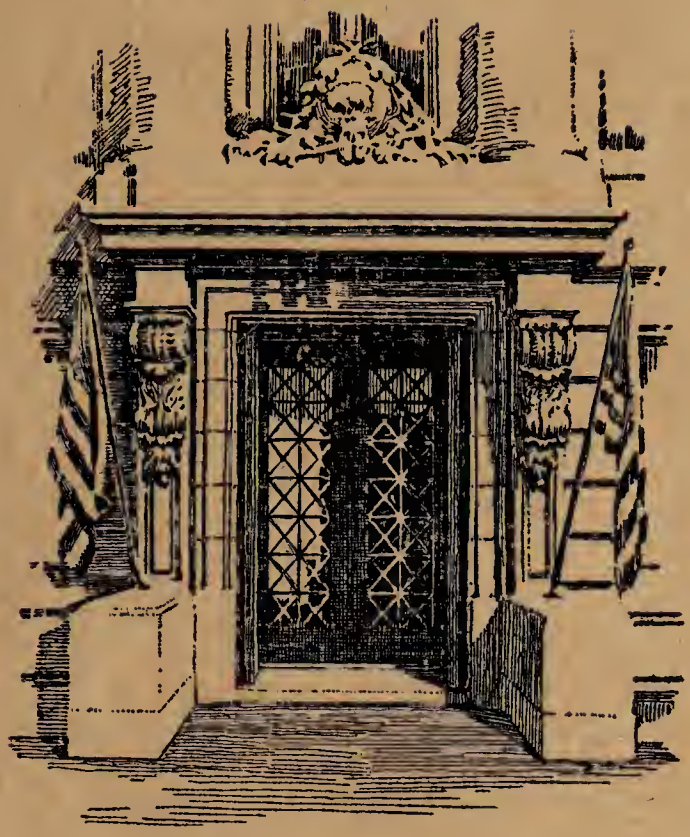
HRDLIČKA, ALEŠ
1906 Contribution to the physical anthropology of California. *Univ. Cal. Publ. Amer. Archaeol. Ethnol.*, v. IV, no. 2, pp. 49–64.
1907 Skeletal remains suggesting or attributed to early man in North America. *Bull. 33 Bur. Amer. Ethnol.*, Washington.
1909 Report on an additional collection of skeletal remains from Arkansas and Louisiana, *Jour. Acad. Nat. Sci. Philadelphia*, v. XIV, pp. 173–249.
1916 Physical anthropology of the Lenape or Delawares, and of the eastern Indians in general. *Bull. 62 Bur. Am. Ethnol.*, Washington. (Reprinted as *Contributions Mus. Amer. Ind. Heye Found.*, v. III.)

KLAATSCH, HERMANN
1908 The skull of the Australian aboriginal. *Rep. Path. Lab. Lunacy Dept. Sydney*, v. I, pt. 3, pp. 43–167.

MARTIN, RUDOLF
1928 Lehrbuch der Anthropologie. 2d. ed. Jena.

OETTEKING, BRUNO
1920 Morphological and metrical variation in skulls from San Miguel Island, California. I.—The sutura nasofrontalis. *Indian Notes and Monogr.*, v. VII, no. 2, pp. 51–85.
1923 On the morphological significance of certain cranio-vertebral variations. *Anat. Rec.*, v. XXV, pp. 339–353.
1924 Declination of the pars basilaris in normal and artifically deformed skulls. *Indian Notes and Monogr.*, Misc. no. 27.

SARASIN, FRITZ
1916–22 Anthropologie der Neu-Caledonier und Loyalty-Insulaner. C. Anthropologie. Berlin.



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AN EXTREME CASE OF ARTHRITIS DEFORMANS IN A SKELETON FROM SAN NICOLAS ISLAND, CALIFORNIA

BRUNO OETTEKING

AMONG the skeletal material in the Museum from San Nicolas island, California, there is a torso of a trunk skeleton, apparently male and of mature age, which represents a case of

arthritis deformans excessively developed to the point of extreme rarity in pathology.

Our specimen comprises the following parts unified by diffuse osseous growth: thoracic vertebræ VII–XII; lumbar vertebræ I–V; sacrum; the adhering ribs VII–XII, the first of which (VII) is reduced by breakage to a splinter of about 5 cm. in length; and finally the left pelvic bone without its pubic part. The straight length of the torso, measured midventral-

FIG. 11.—Ventral view of the arthritic torso. (Phys. Anthr. cat. 900)

FIG. 12.—Dorsal view of the arthritic torso. (Phys. Anthr. cat. 900)

ly, attains 43 cm.

The loci of arthritic degeneration are, as the term implies, the joints. In the intervertebral joints, which are particularly affected, the fibrocartilages (ligamenta intervertebralia) are so extraordinarily enlarged in ossification that they form voluminous bolsters entirely around the adjacent body edges of the vertebræ, especially in

the lumbar region. It appears, however, that the pulpous nuclei of the intervertebral fibrocartilages had remained free from ossification, so that after death these organic parts decayed, leaving intervertebral spaces in their places, as may be observed through the intervertebral foramina and through the fissures on the left side between thoracic vertebræ VII, VIII, and IX, and between thoracic vertebra XII and lumbar vertebra I. The fissures are clearly shown in fig. 11. The ossified ligamentum longitudinale anterius can likewise easily be identified there, extending midventrally between the osseous bolsters into which the intervertebral fibrocartilages have degenerated. Still more substantially ossified is the joint between the last lumbar and the first sacral vertebra, which in fact does not leave the slightest indication of demarcation between the vertebral bodies which here and in the corresponding places run transversely midway through the aforenamed bolsters, as shown by the broken lines in fig. 11.

Solidly merged in each case also are the articular processes of all the adjacent vertebræ, while the spinous processes are free from osteophytic degeneration and fusion, except those of the last lumbar and first sacral vertebræ, which are completely fused, including the intermittent

spaces between the arches of the former and the edges of the entrance into the sacral canal. The latter is laid open along its full extension, as shown in fig. 12, causing a complete longitudinal gap whose edge-to-edge width attains 10–17 mm. This condition of rhachischisis sacralis prevailed apparently during life, since the edges of the gap are smooth, showing no sharpness from breakage in the skeletal state.

The ribs (VII–XII) are likewise completely fused with their vertebral articulations, both in the vertebral bodies and in the transverse processes. Finally, the left hip bone through the greater extent of the sacroiliac articulation, is fused with the sacrum; in the lower part, however, the articulating edges are separated by a very narrow fissure having the appearance of an extended rift in the diffuse osseous growth.

This is the most extreme case of arthritis deformans known to the writer.

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SKELETAL REMAINS FROM TEXAS

BRUNO OETTEKING

DURING the summer of 1929, Mr. E. F. Coffin of the Museum undertook an investigation of a number of burial sites in western Texas.[1] Beginning with a brief survey of a rockshelter site in which Mr. M. R. Harrington had previously worked in a cañon called by him by its earlier name of Eagle cañon, but which he refers to as Bee Cave cañon, Mr. Coffin proceeded thence to Satan cañon, where he continued his excavations. The skeletal material herein briefly described comes from these two sites, No. 891 being from a rockshelter 3¼ miles northeast of Bee Cave cañon, at Chalk draw, Brewster county, the others from the Satan cañon rockshelter, Markward ranch, about 25 miles northwest of Del Rio, Valverde county. The general data pertaining thereto are presented in the accompanying Table I.

As indicated, the skeletons are fairly complete and in a fair to good state of preservation. Nos. 894 and 895 are skulls only, the latter a calvar-

[1] See *Indian Notes*, vol. VI, no. 4, pp. 407–411, October, 1929.

TABLE I

Catalogue No.	Age	Specimen	State of Preservation	Remarks
891	senile	skeleton	good	Also fragmentary bones of a fetus
892	senile	skeleton	good	Burial no. 1
893	mature	skeleton	fair	Burial no. 2
894	senile	cranium	good	Burial no. 3
895	mature	calvarium	good	—

ium, i.e., without its lower jaw. It will be observed that the five individuals whose bones are tabulated were of mature to senile age, which accounts for a certain porosity of the bones, the primary stages in general of osseous atrophy carried to an extreme in the lower jaws, and for the more or less developed arthritic degeneration, particularly in the vertebral joints. Two notable cases, one of arthritis in a metatarsophalangeal joint, and the other, through periostitic degeneration, of concrescence of the right metacarpalia iii-v, obtain, besides spondylitic deformations, in No. 892. These two cases are illustrated in fig. 82.

The osseous relief in the longbones is not strongly pronounced, but the platycnemic condition of the tibiæ in various degrees of development are of significance from the Indian diag-

nostic point of observation. Judging by visual calculation and leaving for a future time the

FIG. 78.—Norma frontalis of skull 895.

metrical investigation of the longbones and their proportional evaluation, the skeletons reveal

approximately medium statures of their erstwhile owners.

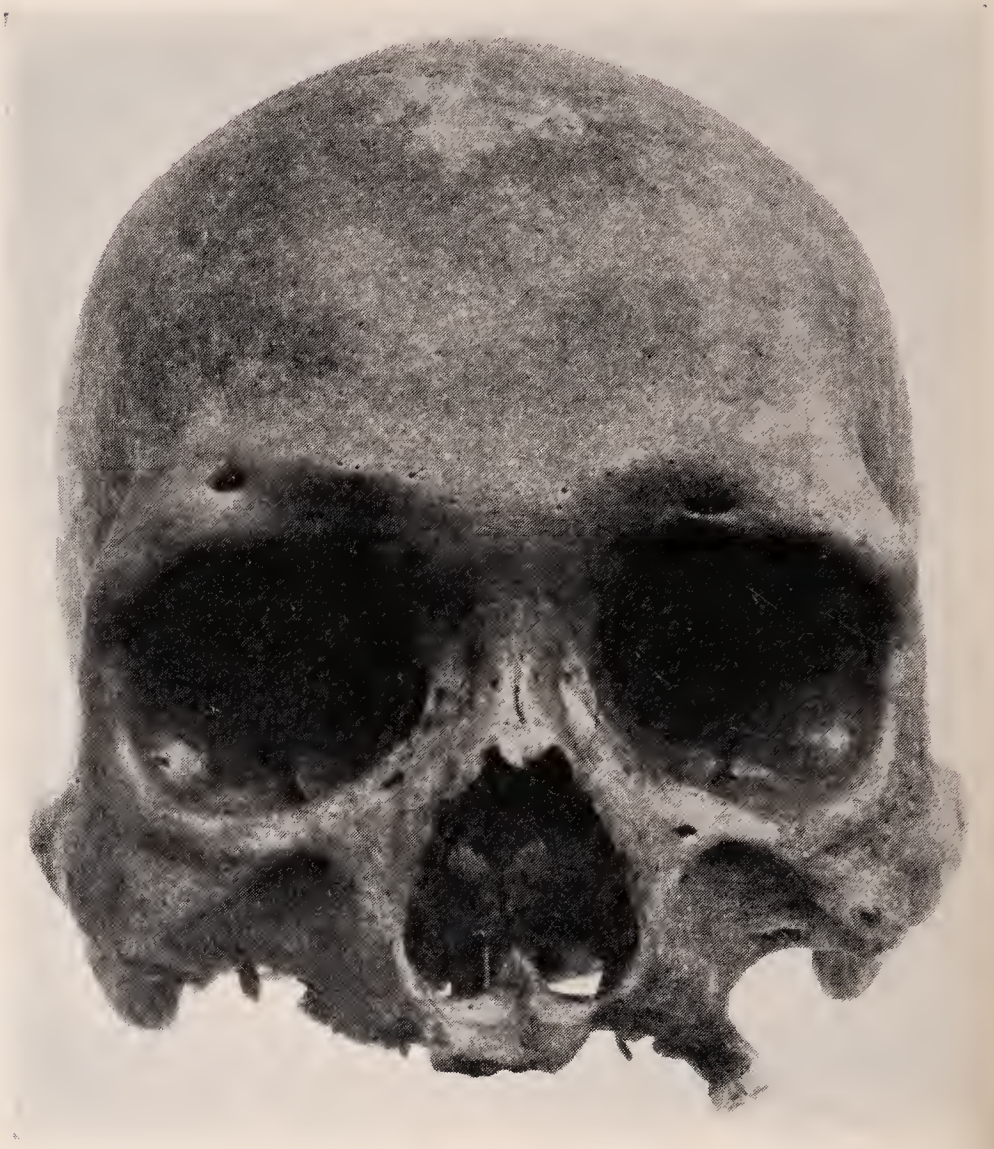

FIG. 79.—Norma frontalis of skull 891.

The skulls number five, four of them crania and one a calvarium. As expressed by their

absolute dimensions, they are of good size, except the female skull (No. 894) which falls short in its principal dimensions by comparison with those of the males. The individual measurements are listed in Table II, where it will likewise be seen that the cranial modules, according to the formula $\frac{L + Br + H}{3}$, range from 150.0-153.7

TABLE II

Measurements	891 ♂	892 ♂	893 ♂	894 ♀	895 ♂
	senile	senile	mature	senile	mature
Cranial	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Length	191	185	183	177	189
Breadth	128	136	137	125	130
Height	131	140	132	122	132
Module	150.0	153.7	150.7	141.3	150.3
Min. front. cr.	95	88	88	85	93
Facial					
Height	71?	70	72	65?	73?
Breadth (bizyg.)	132	144	137?	—	135
Nasal height	54	51	53	54	56
Nasal width	31	25	27	27	29
Orbital height	34	34	33	34	34
Orbital width	43	44	44	43	42
Indices					
Length-breadth	67.0	73.5	74.9	70.6	68.8
Length-height	68.6	75.7	72.1	68.9	69.8
Breadth-height	102.3	102.9	96.4	97.6	101.5
Transv. par. front.	74.2	64.7	64.2	68.0	71.5
Upper facial	53.8	41.7	52.6	—	54.1
Transv. cran. fac.	103.1	105.9	100.0	—	103.9
Nasal	57.4	49.0	50.9	50.0	51.8
Orbital	79.1	77.3	75.0	79.1	80.95

FIG. 80.—Norma lateralis of skull 895.

mm. in the male skulls, while the female reaches only 141.3 mm. If compared with group averages for Eastern Indians[2] extending in the males from 152.2-160.4 mm. and with that of 148.9 mm. for the San Miguel island series in the Museum, it will be seen that the Texas skulls occupy a medium station. Our female skull of 141.3 mm., on the other hand, falls short of both the Eastern Indian range of 146.4-150.0 mm. and the San Miguel island average of 142.6 mm. The most extraordinary feature, however, in the present skulls, is their marked dolichocrany, which in two of them (891, 895) even attains hyperdolichocranial status. The marked length of our crania furthermore is of decisive influence in the length-height proportion where with two exceptions the indices are chamæcranial, while in the exceptions (892, 893) the marked lengths are matched by greater height extensions. The cranial breadth, distinctly small in a general physiological range of from 101-173 mm., has a decided influence in the transverse parietofrontal and craniofacial indices, rendering three crania stenometopic, one mesometopic, and one eurymetopic, which latter,

[2] *Hrdlička, Aleš*, 1916. Physical Anthropology of the Lenape or Delawares. and the Eastern Indians in General, *Bull. 62, Bur. Amer. Ethnol.*, p. 118.

FIG. 81.—Norma lateralis of skull 891.

however (No. 891), with a larger minimum frontal breadth of 95 mm., exceeds all the others. The transverse craniofacial index, besides the narrowness of the skull, is, in turn, decidedly influenced by the bizygomatic breadth, which is quite high in a general physiological range of 100-155 mm., and which also is the cause of conspicuous phænozygy. The upper facial index is illustrative of medium high faces except in No. 892 whose extreme bizygomatic breadth renders its face euryenic. The noses show a tendency toward chamærrhiny, and the orbits are truly mesokonchial with one chamækonchial exception.

The skulls, which have been briefly accounted for metrically here, exhibit pronounced type differences as revealed in figs. 78–81, presenting skulls Nos. 891 and 895 in normæ frontalis and lateralis. Both being hyperdolichocranial, it will be noted in norma frontalis of No. 895 that from the broad bizygomatic basis, which is further emphasized by the broad display of the zygomatic bones and their acute angular approximation toward the frontal plane, the cranial contour tapers into a pronounced crest of the cranial vault, the so-called crista sagittalis. This feature is considerably less expressed in No. 891, which also shows a narrower display

FIG. 82.—Fused hand and foot bones of skeleton 892.

of the zygomatic bones, i. e., giving the impression of a somewhat narrower face and a more evenly vaulted transverse vertical contour. The crista sagittalis is of typical occurrence in the eastern Eskimo and the Australian, and at least one of the Lagoa Santa specimens of the Copenhagen collection; but while the Eskimo has a leptorrhinic piriform aperture, the Australian is chamærrhinic, which would correspond to the decidedly chamærrhinic conditions in our two specimens. Of more advanced morphological standing in these specimens are the well developed canine fossæ. The alveolar ridges, it will be observed, are strongly atrophied.

The most striking feature in norma lateralis is the sharp flexure of the occiput in No. 895. and the resulting almost horizontal course of the inion-opisthion stretch of the occipital outline. The condition here is intensified by the presence of a well developed torus occipitalis. The occipital outline is much more rounded in No. 891, and the entire lateral contour is more evenly elliptic and rather coincides with *G. Sergi's* ellipsoides rotundus, while No. 895, a type of decided morphological inferiority, signifies a pronounced type of ellipsoides sphyroides. Traits of further interest are the high course of

the temporal lines and the smallness of the mastoid processes in No. 895.

Differences of type are an indubitable indication of heterogeneous group composition. Our small series comprises three specimens coinciding with the type of No. 895, and two with No. 891. But, although differing in cranial contour, they all represent the dolichocranial skull form and as such the Southwestern representatives of dolichocrany in contrast with the Northern or, still more distinct, the Northeastern, dolichocranial area.